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DEFENCE R&D DÉFENSE

Efficacy of Radiological Decontamination

D.S. Haslip, T. Cousins and B.E. Hoffarth
Defence Research Establishment Ottawa

Defence R&D Canada
DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 2001-060
August 2001

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DEFENCE R&D DÉFENSE

Efficacy of Radiological Decontamination

D.S. Haslip, T. Cousins and B.E. Hoffarth
Radiation Effects Group
Space Systems and Technology Section

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 2001-060
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Project
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Abstract

Trials of various decontamination methods and materials were carried out by DREO personnel at a French army facility. This was done to validate these materials and techniques for use with radioactive materials. Exterior and interior radiation detectors were used to monitor the progress of the decontamination. It was shown that the Irvin Aerospace CASCAD (CGE 2000) foam was only 59% effective in removing the radioactive contamination in the first attempt, and that even after two more attempts at decontamination (first using the same material with a different method, and finally with French material and methods), the overall decontamination efficacy was only 72%. These results are consistent with previous experiments, although they are poorer than most of these earlier results. It is important to note that without further attempts at decontamination, this vehicle (a CF Grizzly) was still 10000 times too contaminated to be released for unrestricted use by regulatory authorities. This has important ramifications for military operations in contaminated environments.

Résumé

Des épreuves de décontamination de diverses méthodes et de matériaux ont été effectuées par CRDO à un établissement de l'armée française. Ces épreuves ont été accomplies afin de valider l'usage de ces matériaux et techniques pour la décontamination d'équipements contaminées avec des matériaux radioactifs. Plusieurs détecteurs pour le rayonnement ont été placé à l'intérieur et à l'extérieur du véhicule afin d'observer le progrès de la décontamination. Il fut démontré que la mousse CASCAD (CGE 2000) fabriqué par Irvin Aerospace peux enlever seulement 59% de la contamination radioactive dans le premier essai, et même après deux autres essais (utilisant d'abord le même matériel avec une méthode différente, et finalement avec les méthodes et les matériaux français), l'efficacité de décontamination était seulement 72%. Ces résultats sont compatibles avec des épreuves précédentes, bien qu'ils soient au-dessous de la moyenne. Il est important de noter que, sans d'autres essais de décontamination, ce véhicule (un Grizzly des FC) était, d'après les régulateurs, 10000 fois trop contaminée pour être utilisé sans restriction. Ceci a des ramifications importantes pour des opérations militaires dans des environnements contaminées.

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Executive summary

Introduction: The threat of radioactive contamination is one that remains even after the Cold War, although the origin of the hazard is no longer necessarily the detonation of a nuclear weapon. Military operations in contaminated environments carry many difficulties, not the least of which is the decontamination of heavy equipment. This decontamination is important because it may affect how this equipment will be used in future, and whether it can be transported across international borders. In this work, Canadian and French decontamination methods and materials were brought to bear on a radioactively contaminated armoured personnel carrier (the CF Grizzly). Both exterior and interior radiation meters were used to monitor the progress of decontamination efforts.

Results: On average, the first decontamination (with Irvin Aerospace's CASCAD (CGE 2000) foam) removed only 59% of the radioactive contamination. Even after two more decontamination attempts (first with different methods, and then with French material and methods), 28% of the original contamination remained. Upper surfaces of the vehicle seemed to be more readily decontaminated than others, but this is probably attributable to larger quantities of loose contamination being present on the former surfaces at the outset. The results of this study are consistent with previous Canadian trials.

Significance: It is noted that in these trials, the Grizzly was only decontaminated to levels around 50 MBq/m^2. This still leaves the vehicle with a contamination level 10000 times higher than would be required for national and international regulators to certify this vehicle for "unrestricted use" and transport. In the event that DND vehicles became contaminated during military operations, the ramifications of this result would be far-reaching.

Haslip D. S., Cousins T., and Hoffarth B.E. 2001. Efficacy of Radiological Decontamination. DREO TM 2001-060 Defence Research Establishment Ottawa.

Sommaire

Introduction: La menace de la contamination radioactive demeure malgré la fin de la guerre froide, bien que l'origine du risque ne soit plus nécessairement la détonation d'une arme nucléaire. Les opérations militaires dans les environnements contaminées présentent plusieurs difficultés, ci-inclus la décontamination d'équipements lourds. Cette décontamination est importante parce qu'elle peut affecter comment cet équipement sera utilisé à l'avenir, et s'il peut être transporté à travers les cadres internationaux. Dans ce travail, des méthodes et des matériaux de décontamination canadiens et français ont été appliqués sur un véhicule blindé (le Grizzly des FC) qui était contaminé. Des détecteurs de rayonnement placés à l'extérieur et à l'intérieur ont été utilisés pour surveiller le progrès des efforts de décontamination.

Résultats: En moyenne, la première décontamination (avec la mousse CASCAD (CGE 2000) d'Irvin Aerospace) a enlevé seulement 59% de la contamination radioactive. Même après deux essais supplémentaires de décontamination (d'abord avec différentes méthodes, et puis avec les méthodes et les matériaux français), 28% de la contamination originale à demeurée. Les surfaces hautes du véhicule ont semblé être décontaminées plus facilement que d'autres, mais ceci est probablement attribuable à de plus grandes quantités de contamination non-fixée étant présente sur ces surfaces au début de l'essai. Les résultats de cette étude sont compatibles avec les résultats des épreuves précédentes.

Importance: On note que dans ces épreuves, le Grizzly était décontaminé seulement à des niveaux dans la région de 50 MBq/m^2. Le niveau de contamination qui demeure sur le véhicule est 10000 fois plus élevé que ce qui est nécessaire aux régulateurs nationaux et internationaux pour certifier ce véhicule pour toute utilisation et pour le transport. Dans le cas où les véhicules de DND deviendraient contaminés pendant des opérations militaires, les ramifications de ce résultat seraient importantes.

Haslip D. S., Cousins T., et Hoffarth B.E. 2000. L'efficacité de la décontamination radiologique. DREO TM 2001-060 Centre de recherce pour la défense Ottawa.

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1. Introduction

Radiological contamination has been and continues to be a potential problem for military operations. During the Cold War, this hazard derived from forces operating in a fallout field following detonation of a nuclear weapon. In modern operations, the contamination could come from a number of sources. While potential origins still include the nuclear fallout from conventional or improvised nuclear devices, more probable sources are the radioactive debris remaining after (a) the use of an radiological dispersal weapon, or (b) an accident or an act of sabotage at a nuclear facility. All of these scenarios can result in radioactive contamination spread over a wide area.

While contamination of personnel is a difficult issue to manage, a bigger problem may be the contamination of equipment, particularly vehicles. In the eyes of the international community, a contaminated vehicle is nothing more than a large, unsealed radioactive source, and as such is subject to rigorous constraints with respect to its transportation across international borders and its decommissioning and disposal (as specified, for example in national legislation or by the International Air Transport Association (IATA)). In addition, forcing personnel to work in a radioactively contaminated vehicle may be difficult, especially in a non-wartime (eg: peacekeeping) scenario. Thus, decontaminating equipment is an important task.

In September 1999, DREO personnel participated in joint Franco-Canadian trials on radiological decontamination. This included the contamination of a Canadian Forces Armoured Personnel Carrier (the Grizzly) with radioactive material, and several attempts to decontaminate this vehicle with Canadian and French equipment and techniques. This document summarizes the results of these trials.

2. Experiment

The trials were performed at the Centre Décontamination et Études de Protection (DEP) at the Établissement Technique de BourgeS (ETBS) in September of 1999. Sand loaded with radioactive Lanthanum-140 was used as the contaminant. The mean diameter of the sand particles was between 100 and 200 microns, typical of a conventional fallout distribution. Lanthanum-140 is a beta-gamma emitter with a complicated energy spectrum for both betas and gammas. It is a reasonable simulant for the fission products present in fresh nuclear fallout.

The contamination of the vehicle takes place in a contained facility to minimize the airborne radiation hazard. The lanthanum sand falls from an automated system onto a pre-wetted vehicle to enhance adhesion. The contamination of the room is not uniform but is reasonably so over the region in which the vehicle is parked. So-called "witness plates" are set on the floor on either side of the vehicle prior to contamination. They are collected when the contamination has settled, and they are measured to determine the levels of contamination that fell in those areas. This forms the best estimate of the degree of contamination of the vehicle.

Once the radioactive sand has settled out of the air, the vehicle is moved out of the contamination area to an outdoor concrete pad where its exterior contamination distribution is assessed. This is done by ETBS with 77 Geiger tubes mounted on a specially designed steel "cage" (see Figure 1). The cage envelops the vehicle and allows each Geiger tube to be positioned reproducibly at the same location on the vehicle each time the measurement is made. Each Geiger tube is placed about 5 cm from the surface of the vehicle. Since Geiger tubes measure dose rates, and since the contamination pattern on the outside of the vehicle is not uniform, it is difficult to infer contamination levels from this measurement. However, a rudimentary assessment can be made, and the measurements are very useful for identifying the differences in contamination levels over the surface of the vehicle. The Geiger tube measurements are performed prior to decontamination and after each stage of decontamination to monitor progress.

Decontamination was performed by both Canadian and French teams. The Canadian team used Irvin Aerospace's CASCAD (CGE 2000) foam in two ways (Irvin Aerospace Canada Limited is based in Fort Erie, Ontario). In the first trial, the foam was sprayed on, left for 30 minutes, and then hosed off. In the second trial, the foam was sprayed on, scrubbed, and then hosed off. The French team then applied the French decontaminant (detergent and water at 80 degrees Celsius and 150 bars pressure), scrubbed, and then hosed it off.

Throughout these trials, interior dose rates were measured with Canadian electronic dosimeters. The 10 dosimeters (Siemens EPD-2s) were placed at various locations throughout the vehicle, recording an integrated dose to memory every two minutes. These doses were downloaded to a PC following the experiment, permitting an assessment of the dose rate at each location throughout the trial.

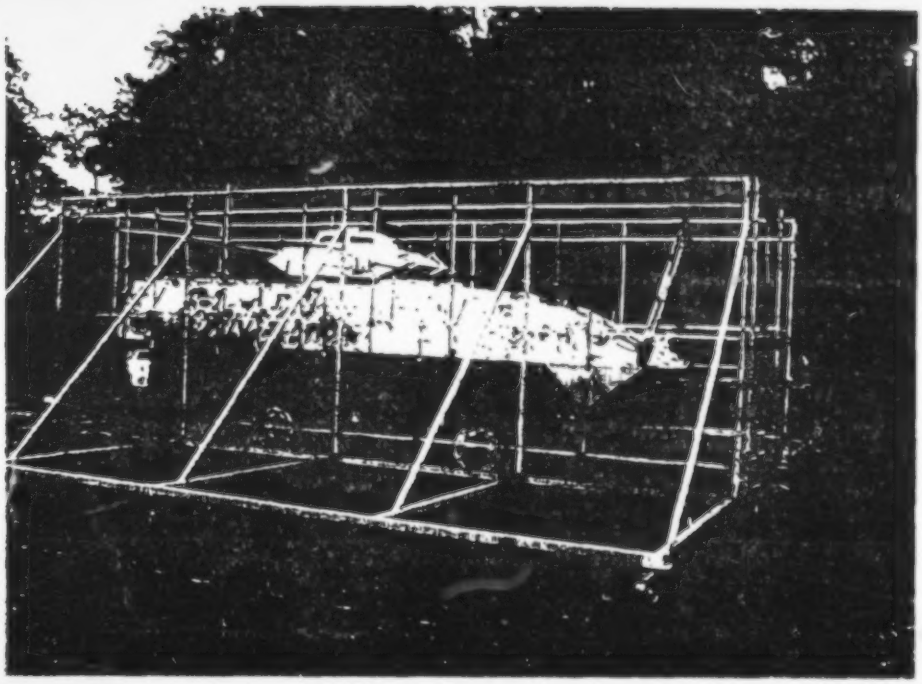

Figure 1. *Measuring contamination levels with the ETBS cage. Seventy-seven Geiger tubes are suspended by the metal structure. The cage rides on wheels, allowing it to be rolled into place, enclosing the vehicle.*

3. Contamination Levels

As noted above, the first measurement of the vehicle contamination is performed in the fallout room. One row of witness plates is placed on each side of the vehicle prior to contamination and is collected following contamination and measured. Figure 2 shows these measured contamination levels as a function of distance along the length of the vehicle. The series labeled "left side" denotes the side on which the driver sits. Points corresponding to the front of the vehicle lie on the left side of the graph. The contamination level on the witness plates is 180 ± 40 MBq/m^2. The figure shows that the right side appears to be slightly more contaminated than the left, and that the front-to-back variation is the dominant one, in the neighbourhood of 23% (evident from the uncertainty quoted above).

The second measurement of the vehicle contamination takes place in the Geiger tube cage. Figure 3 is an "unfolded" picture of the Grizzly with the Geiger tube measurement points superimposed. The points are colour-coded according to the first measurement of the contamination. As expected, the contamination levels are highest on the horizontal top surfaces of the vehicle, where the sand was able to fall and remain. Contamination levels are lower on near-vertical surfaces, where it is harder for sand to settle and cling. Contamination levels are lowest on down-facing surfaces, to where contamination could not fall directly from above. Contamination on the right

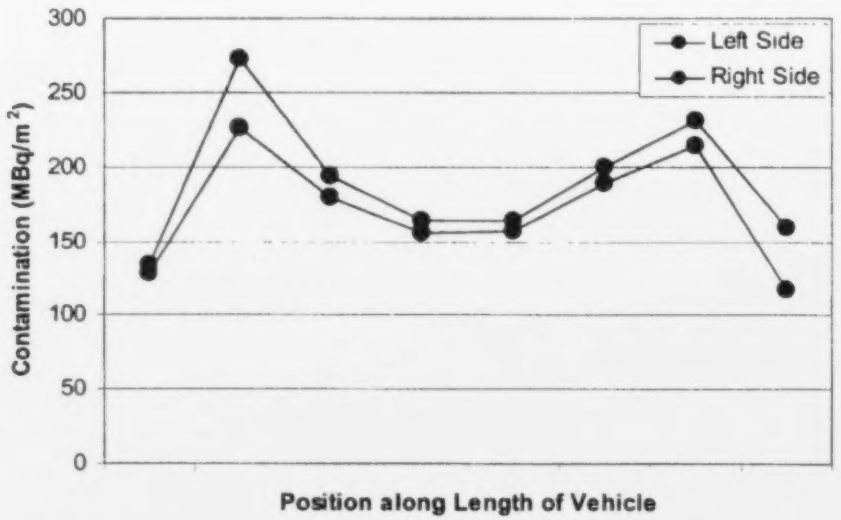

Figure 2. *Contamination levels measured on the witness plates next to the Grizzly in the contamination area.*

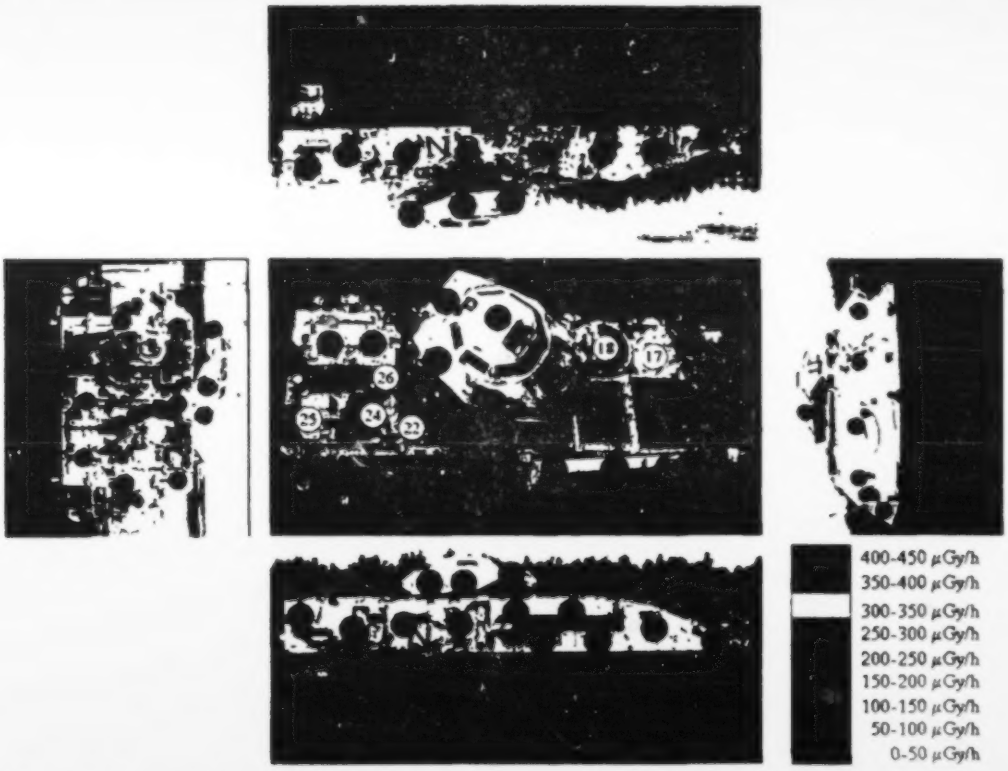

Figure 3. *Contamination levels measured with the Geiger tube cage immediately after contamination.*

side of the vehicle is slightly higher than on the left, in agreement with the witness plate measurements above. Previous measurements at DEP [1] have suggested that the conversion factor from dose rates measured with the cage to contamination levels should be approximately 1.65 (μGy/h)/(MBq/m^2). This would imply that contamination levels on the vehicle ranged from 4 to 260 MBq/m^2; the maximum of this range is in good agreement with the maximum contamination level measured on the witness plates. It is difficult to get a second comparison point because contamination levels on the witness plates vary only because of the irregularities in the contamination system itself, whereas contamination levels on the vehicle also depend on the stickiness of vehicle surfaces and their variation from horizontal.

4. Decontamination

4.1 Cage Measurements

A large quantity of data was collected in these trials, especially with respect to external contamination measurements. Before decontamination and after each of three decontamination attempts, the external contamination levels were measured in the Geiger tube cage. While all of these data give a good picture of the state of the vehicle as a function of time, the interpretation of decontamination effectiveness at individual locations on the surface of the vehicle is neither feasible nor useful. Variations in the surface and in the adhesion of the contamination to the surface, not to mention the complexities in what happens to the contamination as it is washed away from a given location, contribute to a very complicated picture of decontamination efficacy when viewed location by location. Figure 4 shows this clearly in a box and whisker plot of the Geiger tube measurements. While the upper and lower quartiles of these data are not widely spread, it is clear that some data points lie far away from others. For example, after the first decontamination, one of the locations was actually more contaminated than it had been the first time (a result of ^{140}La transfer from a more contaminated area to a less contaminated one).

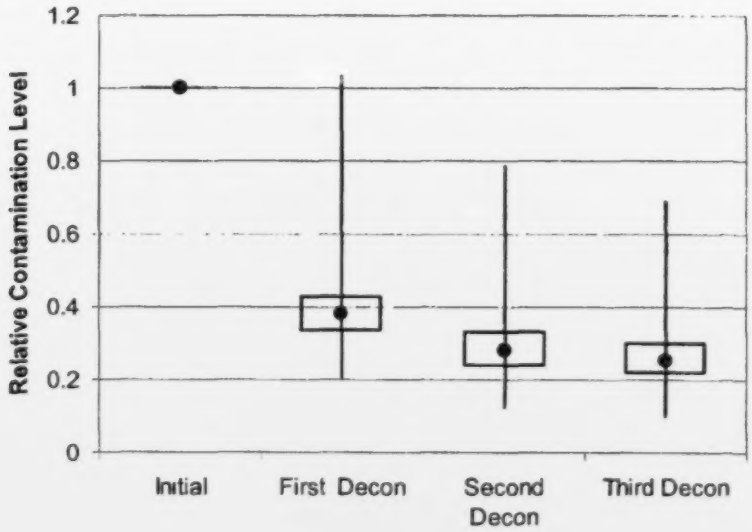

Figure 4. *Box and whisker plot showing the relative contamination levels (according to measurements from the Geiger tube cage) on the vehicle after contamination and after each of the three phases of decontamination. In a box and whisker plot, the vertical line defines the maximum and minimum of the distribution, the box defines the upper and lower quartiles, and the circle denotes the median.*

To ease analysis of these data, the 77 Geiger tube positions have been grouped into 12 regions, depending on where on the vehicle they fall. These 12 regions are:

- The top surface of the turret
- The top surface of the vehicle, forward of the turret
- The top surface of the vehicle, aft of the turret
- The top surface of the "hood" of the vehicle
- The left (driver's) side of the turret
- The right side of the turret
- The upper part of the left side of the vehicle
- The upper part of the right side of the vehicle
- The underside of the vehicle "hood"
- The rear of the vehicle
- The lower part of the left side of the vehicle
- The lower part of the right side of the vehicle

The relative contamination levels (normalized to unity initially) are shown in Figure 5. This is much easier to look at than plots of 77 individual data sets and allows one to see patterns in the decontamination efficacies.

The first decontamination reduced the contamination level by 60% on average, with 73% removed by the final measurement. The semi-log plot in Figure 5 (in which regions with contamination levels falling by identical factors are represented by parallel lines) shows that the greatest difference in decontamination efficacy occurred during the first decontamination, with later attempts producing more or less similar results in all areas. The greatest outlier is the underside of the "hood" or "nose" of the vehicle. This region had very low decontamination efficacy, but this was also the area with the lowest initial contamination levels. The former result may be a consequence of the latter, in that none of the contamination initially present on this surface was loose, but all was adhered to the surface in some way making decontamination more difficult. On the other extreme, the top surfaces (in red in the plot) show the largest decontamination efficacies, an indication that some of the contamination that was initially present was loose, and thus quite easy to remove.

The behaviour of the 12 data series in Figure 5 suggest an additional grouping of the measurement points with the goal of further simplifying the data analysis. In this new scheme, the measurement points are put in the following three groups:

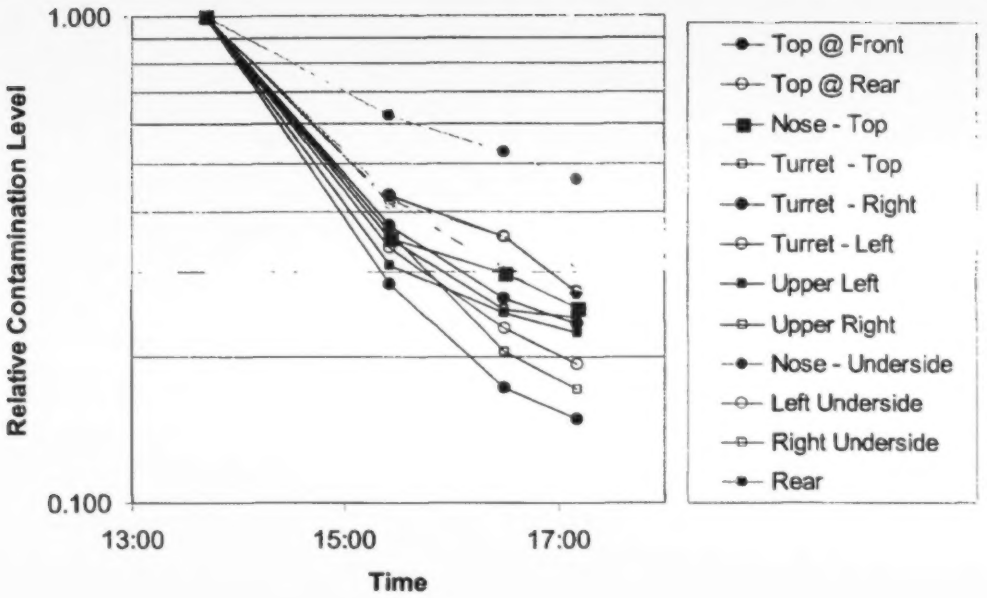

Figure 5. *Relative contamination levels (according to Geiger tube readings) as a function of time. The 77 Geiger tube readings are grouped into 12 regions, shown in the legend. The four measurement times denote the measurement following contamination and each of the measurements following the three decontamination attempts.*

- "Up-facing" surfaces: the four largely horizontal surfaces facing up
- "Side-facing" surfaces: the sides of the turret and vehicle that are mostly vertical but face up slightly
- "Down-facing" surfaces: all of the surfaces whose normal is below the horizontal

Figure 6 shows the relative decontamination efficacies for these three groups, plus the overall averages. The error bars shown are the standard deviations of the groups. The trends of the data are identical to those discussed above. Namely, the "up-facing" surfaces show the largest decontamination, whereas the "down-facing" surfaces show the converse trend. Further, the differences between the data sets are largest following the first decontamination, and are more similar in the second and third attempts.

4.2 Internal Measurements

As discussed previously, ten Canadian dosimeters were placed at various locations inside the vehicle to monitor the dose rates as a function of position throughout these trials. There is no need to address each of these detectors individually, but it is

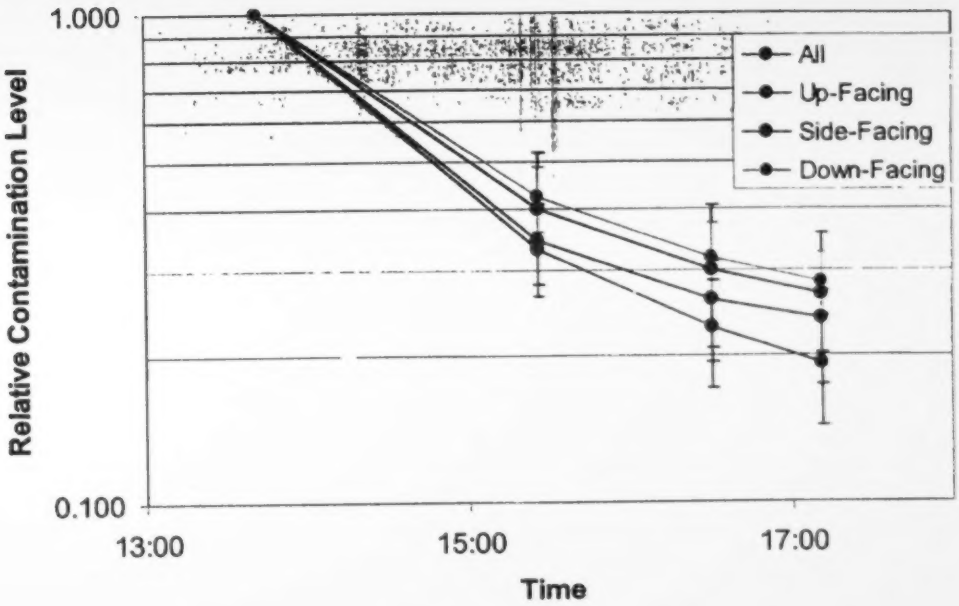

Figure 6. *Relative contamination levels (according to Geiger tube readings) as a function of time. The 77 Geiger tube readings are grouped into 3 regions, shown in the legend. The overall averages are also shown. The error bars are standard deviations for the distributions.*

worthwhile to consider a selection of these, and to compare their results to that of the exterior measurements.

The following locations within the vehicle are chosen, to give a variety of surfaces, close to different parts of the exterior of the vehicle. The chosen locations are:

- The driver's seat: situated in the nose of the vehicle, relatively low
- At head height in the turret: high in the vehicle, and close to the contamination itself
- Left Passenger Bench: specifically, on the part of the bench closest to the rear doors
- Engine block: at waist height, immediately behind the engine compartment.

Figure 7, Figure 8, Figure 9, and Figure 10 show the dose rate measured by these dosimeters as a function of time. For comparison, the relative contamination levels measured by the Geiger tube cage (and shown in Figure 6) are also shown in these graphs. The scale of the secondary y-axis has been adjusted so that the interior dose rates and the relative contamination levels coincide at the first cage measurement.

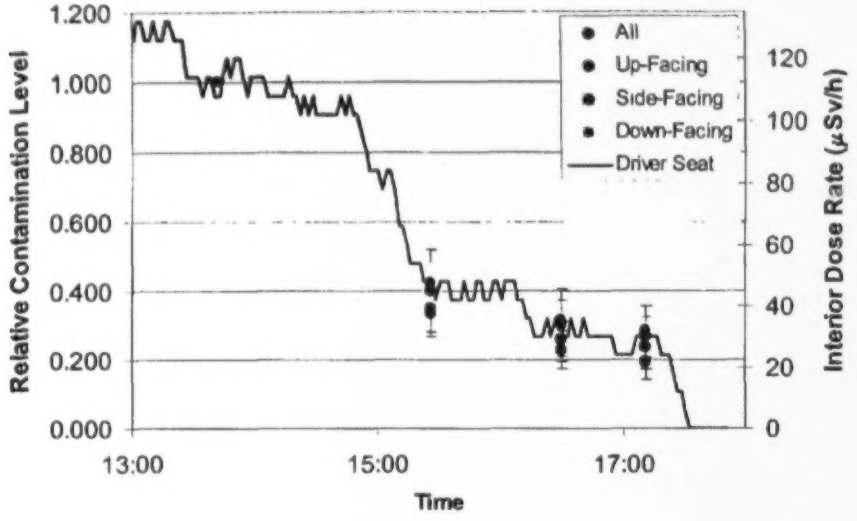

Figure 7. *External and internal measurements of contamination. The data points are the contamination levels measured by the Geiger tube cage for each of the three surfaces defined in the previous section. The line is the dose rate measured by the dosimeter sitting on the driver's seat. The dosimeter dose rate falls to zero at 17:30 when the dosimeter when the dosimeter is removed from the vehicle.*

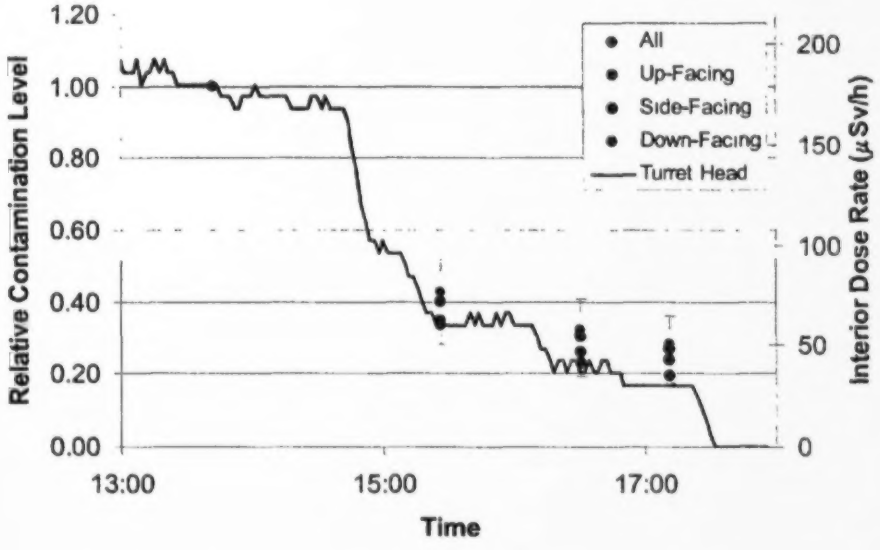

Figure 8. *As in the previous figure, but now the line is for a dosimeter at the head position in the turret.*

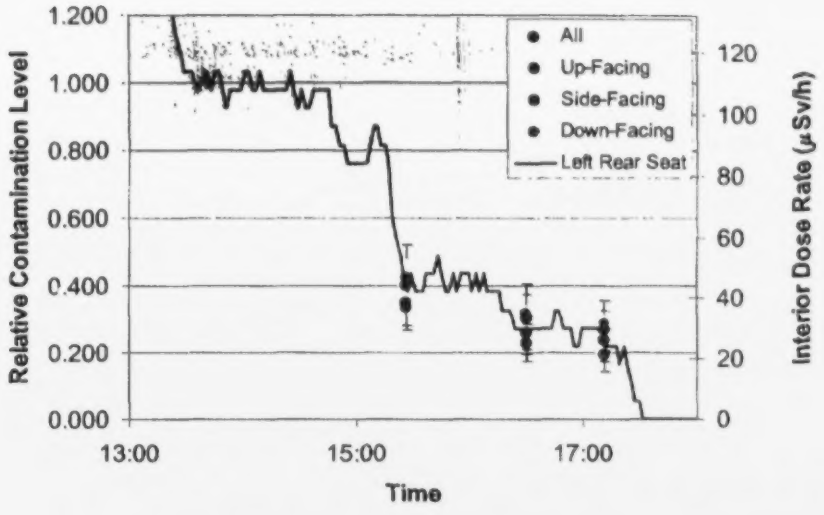

Figure 9. *As in the previous figure, but now the line denotes the dose rate on the left passenger bench, near the rear of the vehicle.*

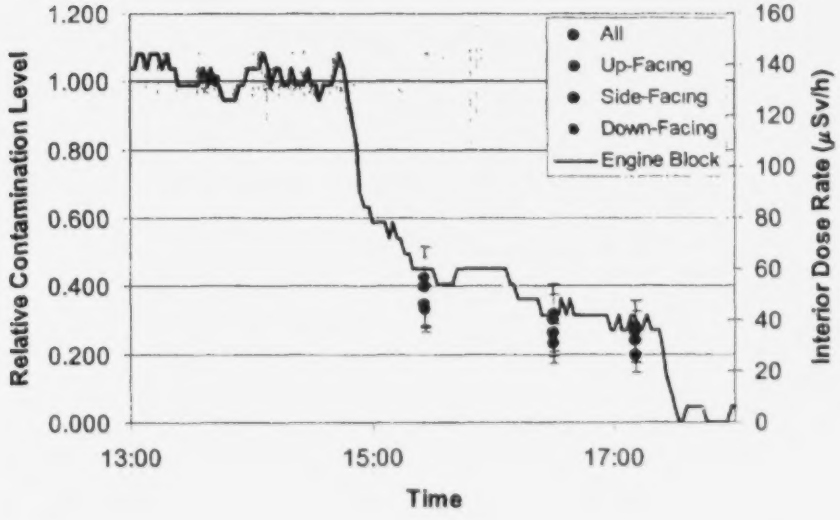

Figure 10. *As in the previous figure, but now the line denotes the dose rate measured at waist height, immediately behind the engine compartment.*

The interior dose rate plots are characterised by a certain amount of jaggedness. This is caused by round-off error in the dosimeters (whose dose resolution is only 1 μSv). It is possible to remove this by smoothing, but the data have already been averaged over 10-minute periods, and further smoothing starts to impact an analysis of the time evolution of the contamination. All of the dosimeter plots also show a decrease to zero at around 17:30; this is due to the dosimeters being removed from the vehicle at the end of the experiment, not to a complete decontamination.

All four interior dose-rate histories are in excellent agreement with the exterior contamination measurements. This supports the trivial result that the dose rate inside the vehicle is proportional to the contamination outside. Actually, the result in this case is more important for the following reason. Despite attempts to make the Grizzly waterproof, a considerable quantity of liquid entered the vehicle during the decontamination process. This liquid was found to contain Lanthanum-140 and it was thought that this interior contamination of the vehicle might have spoiled attempts to measure protection factors. However, it appears based on these results that the contribution to interior dose rates from this liquid is small, probably because the concentration of Lanthanum-140 in this liquid is also small.

The interior measurements are actually good enough to show more than a simple consistency with exterior measurements. Indeed, the interior profiles seem to be precise enough to identify one or other of the exterior "surface classes" as being a chief contributor to the dose rate at a given interior location. For instance, both the driver's seat measurement and the rear bench measurement follow closely the trend for the "down-facing" surfaces. This stands to reason, since both locations are closest to surfaces in that category, and thus it makes sense that the trends in the latter would influence trends in the former. Conversely, the dose rates for the head position in the turret follow the "up-facing" data. This also makes sense, since this measurement point is very close to "up-facing" surfaces and far from any "down-facing" ones. The one example that does not make as much sense is the engine compartment data. These data seem to follow "down-facing" trend closely, although one might expect a larger contribution from "side-facing" surfaces to this measurement point. Perhaps interior shielding has affected this result. It should be noted that, while engine block shielding normally has an enormous impact, in this vehicle most of the mass of the engine had been removed.

4.3 Summary

Table 1 summarises the results of the decontamination trials by providing, for each of the three vehicle regions, the percentage of the original contamination that remains following each of the three decontamination stages. The table also shows the overall averages. The uncertainties shown are standard deviations of the individual measurements. The table also shows decay-corrected numbers. One must remember that because the contamination is radioactive, the quantity of contamination will decrease with time even in the absence of any effort to decontaminate. Moreover, since the half-life of Lanthanum-140 is only 40.22 hours, this effect is considerable,

Table 1. Decontamination efficacies, both overall and for each of the three surface regions. Both raw and decay-corrected values are shown.

	Decontamination Efficacy				Decontamination Efficacy (Decay-corrected)			
	Top	Side	Dbl.	All	Top	Side	Dbl.	All
First Decontamination	67 ± 7	66 ± 6	58 ± 6	60 ± 12	66 ± 7	64 ± 6	56 ± 7	59 ± 12
Second Decontamination	77 ± 6	74 ± 5	68 ± 6	70 ± 11	76 ± 6	73 ± 5	67 ± 6	68 ± 11
Third Decontamination	81 ± 5	76 ± 4	72 ± 4	73 ± 9	80 ± 5	75 ± 4	70 ± 4	72 ± 10

amounting to approximately 6% over the duration of the experiment. The decay-corrected figures are on the right side of the table.

The table shows that the decontamination was 59% effective the first time, and 72% overall. Previous work [1] has shown that the effectiveness of the decontamination can range between 56% and 86%, primarily based on the level of experience of the users. Thus, the values presented in this report are consistent with former work, but at the lower end of the range. This is perhaps due to the condition of the vehicle surface, which was initially very sticky, having been covered by adhesive. However, since this adhesive was used to attach Velcro strips, which were in turn used to mount additional armoured plates, the situation is not entirely unrealistic.

It would obviously be desirable to compare the effectiveness of the various methods of decontamination. Unfortunately, the data collected in this one-day trial are insufficient to do this. The first decontamination removed a lot of relatively loose contamination, and attempting to compare later attempts on the same (now relatively clean) vehicle would be futile. What would be required is a contamination / decontamination cycle for each method of decontamination, preferably starting with a clean vehicle each time. This, however, is a much more costly experiment. Future trials with this and other decontamination techniques will help to address these concerns.

Finally, the limitations of current decontamination technology should be noted. This vehicle was contaminated at levels up to about 250 MBq/m^2 (such a contamination level could be found 100 km downwind of a 20 kT nuclear weapon). Even with a decontamination efficacy of 80% on the most highly contaminated surfaces, this means that the residual contamination following three decontamination attempts remains at 50 MBq/m^2. With national and international regulatory limits [2,3] on radioactive materials becoming active at levels of around 0.005 MBq/m^2 (within a factor of 10, depending on the particulars of the contamination), it is apparent that we are a factor of 10000 away from being able to decontaminate a vehicle in the field to a level that is acceptable for continued and unrestricted use. The implications of this fact alone are staggering.

Table 1. Decontamination efficacies, both overall and for each of the three surface regions. Both raw and decay-corrected values are shown.

	Decontamination Efficacy (%)				Decontamination Efficacy (Decay-corrected %)			
	Up	Side	Down	All	Up	Side	Down	All
First Decontamination	67 ± 7	66 ± 6	58 ± 6	60 ± 12	66 ± 7	64 ± 6	56 ± 7	59 ± 12
Second Decontamination	77 ± 6	74 ± 5	68 ± 6	70 ± 11	76 ± 6	73 ± 5	67 ± 6	68 ± 11
Third Decontamination	81 ± 5	76 ± 4	72 ± 4	73 ± 9	80 ± 5	75 ± 4	70 ± 4	72 ± 10

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5. Conclusions

This work has demonstrated the effectiveness of Canadian and French methods for the decontamination of a Canadian Forces Armoured Personnel Carrier. On average, contamination levels were brought down by 59% following a single decontamination, and down by 72% following three separate attempts. These values are consistent with previous trials with the Canadian decontamination foam. Due to the limited nature of the trial, the different methods of decontamination could not be compared. Upward-facing, horizontal vehicle surfaces were observed to show the best decontamination, but this is likely due to larger amounts of very loose contamination that were on these surfaces prior to decontamination.

The results of this work are supported by a plethora of measurements both outside and inside the vehicle. All of these are in excellent agreement. The interior measurements allowed us to demonstrate that while liquid ingress does occur during decontamination, the levels of contamination in this liquid are not significant relative to those outside the vehicle. More important, they do not contribute significantly to the dose rate to personnel inside the vehicle.

Perhaps the most important result of this work is the demonstration that none of the decontamination methods employed in these trials was capable of decontaminating this vehicle to levels acceptable to regulators for unrestricted use. In fact, contamination levels on the vehicle remained at levels approximately 10000 times larger than unrestricted use levels. While such issues would probably not be enough to affect operations in an actual wartime scenario, they would definitely affect peacekeeping operations, not to mention the tasks occurring after the resolution of a wartime conflict.

6. References

1. Heimbach C.R. and Oliver M.A. (1998). Research Project of the Radiation Fallout Tests at Etablissement Technique de Bourges (ETBS) (ATC-8124). U.S. Army Aberdeen Test Center.

2. Director General Nuclear Safety (2000). Nuclear Safety Orders and Directives.

3. Canadian Nuclear Safety Commission (2001). Regulations under the Nuclear Safety and Control Act. http://www.nuclearsafety.gc.ca/eng/licensees/proposed_regulations.htm.

UNCLASSIFIED
SECURITY CLASSIFICATION OF FORM
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DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

Defence Research Establishment Ottawa
Ottawa, Ontario
K1A 0Z4

2 SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

UNCLASSIFIED

3 TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

Efficacy of Radiological Decontamination (U)

4 AUTHORS (Last name, first name, middle initial)

Haslip, Dean S.; Cousins, Tom; and Jones, Trevor A.

5. DATE OF PUBLICATION (month and year of publication of document)	6a NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)	6b NO OF REFS (total cited in document)
August 2001	14	3

7 DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

DREO Technical Memorandum

8 SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Space Systems & Technology Section
Defence Research Establishment Ottawa
Ottawa, Ontario K1A 0Z4

9a PROJECT OR GRANT NO (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)	9b. CONTRACT NO (if appropriate, the applicable number under which the document was written)
6qe11	

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NOS (Any other numbers which may be assigned this document either by the originator or by the sponsor)
DREO Technical Memorandum # TM 2001-060	

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Trials of various decontamination methods and materials were carried out by DREO personnel at a French army facility. This was done to validate these materials and techniques for use with radioactive materials. Exterior and interior radiation detectors were used to monitor the progress of the decontamination. It was shown that the Irvin Aerospace CASCAD (CGE 2000) foam was only 59% effective in removing the radioactive contamination in the first attempt, and that even after two more attempts at decontamination (first using the same material with a different method, and finally with French material and methods), the overall decontamination efficacy was only 72%. These results are consistent with previous experiments, although they are poorer than most of these earlier results. It is important to note that without further attempts at decontamination, this vehicle was still 10000 times too contaminated to be released for unrestricted use by regulatory authorities. This has important ramifications for military operations in contaminated environments.

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Radiation Detection, Contamination, Decontamination, Foam, Vehicle Protection Factor

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